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Shoe-String Automation

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Abstract

Faced with a downsizing organization, serious budget reductions and retirement of key metrology personnel, maintaining capabilities to provide necessary services to our customers was becoming increasingly difficult. It appeared that the only solution was to automate some of our more personnel-intensive processes; however, it was crucial that the most personnel-intensive candidate process be automated, at the lowest price possible and with the lowest risk of failure.

This discussion relates factors in the selection of the Standard Leak Calibration System for automation, the methods of automation used to provide the lowest-cost solution and the benefits realized as a result of the automation.

Introduction

The Oak Ridge Metrology Center (ORMC) provides a wide spectrum of calibration services to the Y-12 National Security Complex, as well as, to extra-company customers. Recent budget reductions had not only limited funding for automation projects but had also resulted in the reduction of personnel. To further complicate the situation, the aging workforce in the laboratory would mean several experienced metrologists would retire in the near future with a low probability of receiving approval to replace them. ORMC was faced with the responsibility for maintaining the current level of service to customers with less resources. Automation of some processes appeared the only likely solution. Identification of the best process for automation was crucial. Funding for the automation project was also very limited and must be used wisely as future automation funding was likely to hinge on the success of this automation project.

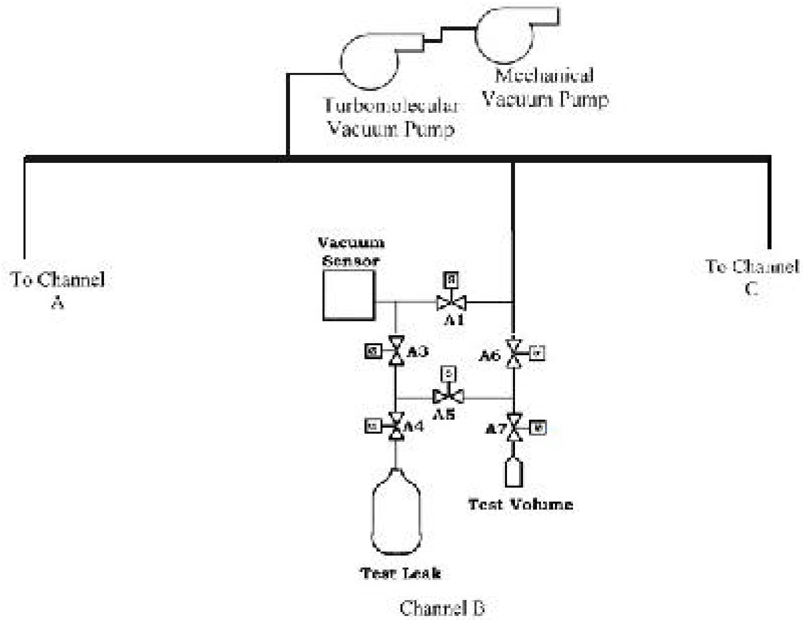

Figure 1: Leak Stand Piping Diagram

Selection of the Process for Automation.

The first step in the automation process was selecting the process for automation. Candidate processes were identified in a specific area of the laboratory. Next each process was evaluated to determine if it was technically possible to automate it using reasonable technical methodologies. Those processes which were determined to be technically unreasonable to automate were excluded from further consideration. The remaining processes were evaluated for the amount of personnel resources required for performance using current manual methods of calibration, available automation strategies and their costs and the likely benefits to be realized from automation of each process. Following performance of the analysis, the Standard Leak Calibration System was selected as the best candidate for automation.

Discussion of the Pre-Automation Standard Leak Calibration System.

The original leak calibration system consisted of a cabinet of valves, vacuum pumps, vacuum manometers, timers and associated manual electrical control switches as depicted in figure 1. The leak calibration stand is capable of simultaneously calibrating three leaks. Leaks were calibrated using the *PªV* method of leak calibration. This process consisted of pumping down a standard leak connected to a piping system which included an evacuated, valve-isolated standard volume. Following the initial pumpdown, pressure was allowed to rise (due to the leak) to a pre-determined value. After reaching this value, the valve to the calibrated, evacuated volume was manually opened and a timer was started. Following recovery of the system pressure to the pre-determined pressure, the timer was stopped and time recorded. This elasped time, along with the known standard volume was used to calculate the leak rate of the standard leak. These values were then used in further calculations to compensate the values for temperature and pressure effects. This test was then repeated again using the same standard volume then twice again using a different volume. A typical test run for a single volume could encompass a complete work day with an entire four-test set comprising up to four days.

Operation of the system required the operator to manually manipulate the valves using electrical switches while monitoring system pressure and time. Distractions from other leak calibration tests, other calibration requirements or simple (and understandable) boredom and inattention often caused the operator to miss a key valve/timer manipulation point and necessitated re-performance of the calibration test.

All of the valves were electro-pneumatically operated and the vacuum pressures for all three channels were electronically measured using capacitance manometers. All key interfaces to the process were electrical/electronic making it an excellent, low-risk choice for automation with a personal computer.

Based on the above discussion, the Standard Leak Calibration System was selected as the best candidate for automation.

Selection of the Automation Method

Available resources and funding factored largely into the selection of the automation method. A look around the laboratory revealed a popular laboratory automation software package of the version which permits generation of stand-alone executable applications. Each of the three calibration channels was equipped with a capacitance manometer, however, the three manometers were multiplexed into one indicator/signal conditioner. A visit to the facility's surplus equipment warehouse resulted in two additional capacitance manometers/signal conditioners.

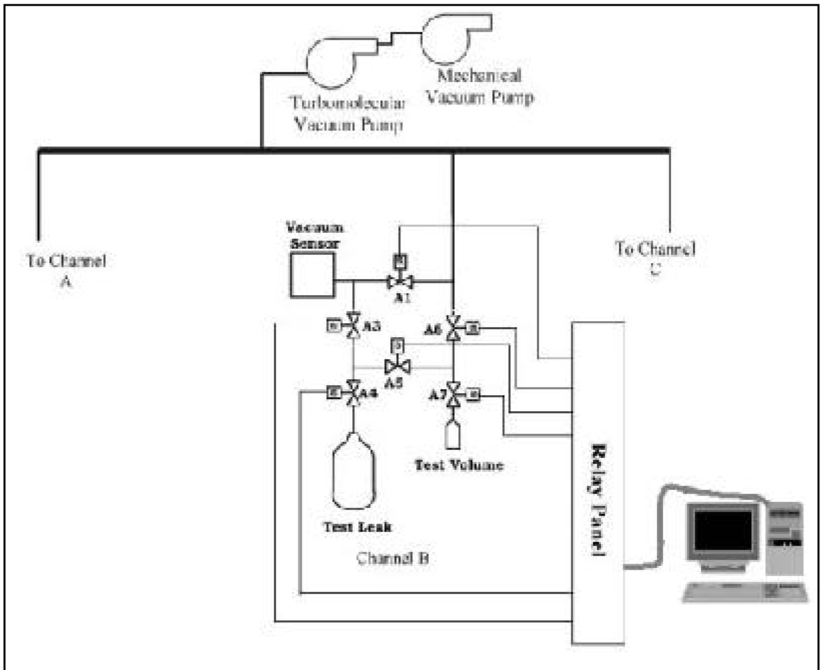

Figure 2: Post-Automation Diagram

A review of the operating system and hardware requirements for the laboratory automation software package indicated that Microsoft® Windows 95 and a fairly low-level of hardware were required for successful operation of the software package. This permitted the use of a surplus computer made available as a result of the retirement of an employee.

The only remaining hardware required for complete implementation of the automation project was a computer interface card consisting of analog inputs and contact inputs and outputs. Due to the current requirements of the solenoid valves, an interposing relay was required for each contact output. The total cost of this computer interface card and interposing relays was $1,600. The hardware for the implementation of the automation project is shown in figure 2.

Development and Integration of the Automation System Hardware/Software

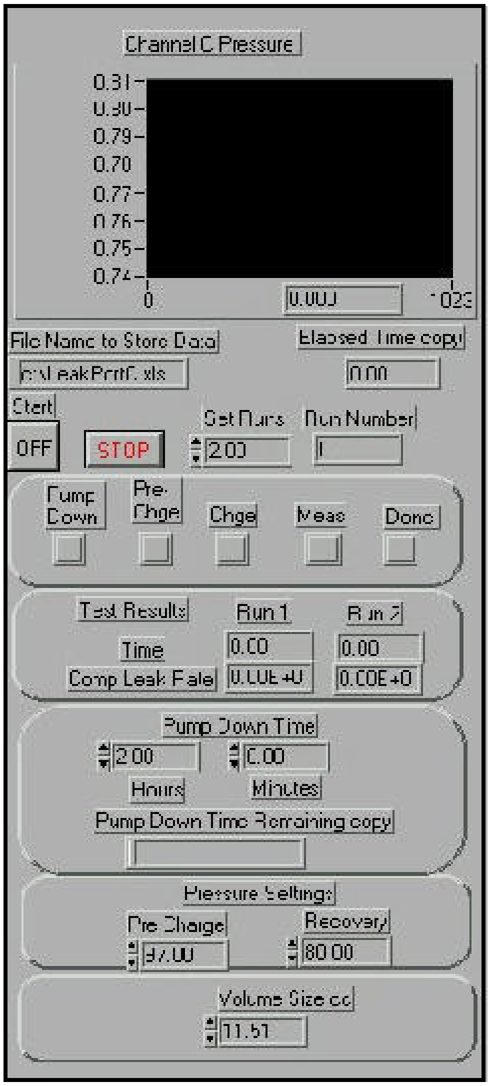

Figure 3: Control Screen

Development of the software configuration was commenced immediately upon determination of the specific computer interface equipment. Concurrent with the software development, hardware was ordered and system hardware re-configuration was begun.

Special attention was given to the hardware modifications in the leak calibration stand to maintain the ability to perform the calibration manually should the automatic system be out of service for any reason. This philosophy also permitted the performance of hardware modifications, software development and debugging and system check-out without impacting the work flow of the calibration stand.

Another goal of the automation project was to implement the automatic system in a manner which essentially emulates the current manual operation of the system. This takes advantage of the current operator's familiarity with the system and minimizes revisions to the current written operating procedures. Figure 3 shows one channel of the three channel control screen which is used by the operator to calibrate the leaks using the automated system.

An opportunity was also capitalized upon to eliminate errors associated with transcription of data during the calibration test. Several instances of improper transcription, transposing, etc. had occurred during recent months when transferring data from lab notes to a spread sheet data form. A feature within the laboratory automation software package permitted Direct Data Exchange (DDE) links with Microsoft® Excel data sheets. The new software application package was designed to automatically record the actual test data in the appropriate columns of a data sheet to eliminate the errors associated with manually recording the data.

Equipment Installation and Testing

Equipment installation was planned to cause the minimum disruption in work flow on the calibration stand as possible. The only calibration stand down-time was due to the need to replace Single-Pole-Single-Throw (SPST) valve Open-Close switches with Single-Pole-Double-Throw switches with a

Center-Off position to provide for Closed-Open-Automatic valve operations. The total down time for switch replacement and re-evacuation of the stand was approximately 1 shift. The remainder of the equipment installation was performed while the stand was operating.

Following the installation of the hardware and software, the analog inputs to the computer were calibrated and the computer timer was certified. The capacitance manometers were calibrated using both the digital display and the analog outputs.
The calibration stand was then operated by the operator in the manual mode while the software system "followed along" and its response to the inputs were monitored using the indicator lights on the relay panel. This permitted actual verification of the proper sequencing and operation of the software valve controls without actually operating the valving. It also permitted verification of the operation of the capacitance manometer analog outputs and their correlation with the digital display values.

After "follow along" mode of operation had provided confidence that the automatic control system was capable of controlling the leak calibration stand, a completely-automatic test run was commenced with a fast, recently-calibrated leak attached to reduce testing time. The results of the first automatic test was compared with the previous manual test results for the leak under test. Several additional automatic tests were run with the fast leak to verify repeatability. Additional tests were performed with very slow leaks to detect any timing problems which may not have been apparent with the fast leak. The correlation of the leak rates obtained using the automatic calibrations with the values obtained using previously-obtained manual leak rate values was very good. The repeatability of test results between test runs was much better using the automatic calibration than had been previously obtained using manual calibration techniques. This was attributable to the absence of the human time response factor in the automatic testing process.

Results of the Automation

The newly-automated system permits the simultaneous calibration of three leaks on a stand. The involvement of the metrologist in the calibration is now limited to connection and disconnection of the leaks from the test stand, set up of the test parameters and clicking the start "button" on the screen. Posting of data into the final data sheet is now performed automatically. Results of the calibrations performed by the automated system indicated much more consistent correlation between leak rates than had been previously obtained using the manual technique. This was expected, especially on the faster leaks, due to the removal of the human reaction time from the process.

Due to production requirements, a new uncertainty analysis has not yet been performed. The existing uncertainty analysis was reviewed with respect to the revised component uncertainties to ensure that the new devices provided uncertainties at least as good as the old devices and that the uncertainty of the process had not been worsened by the automation project. A new uncertainty analysis is planned in the future.

Future Automation Plans

Automation of the second leak calibration stand has already commenced. To date, all hardware has been installed, software has been copied from the first leak stand and modified to suit the second leak stand. Initial testing indicates that the results of the second automation project will be as positive as the first. The computers controlling each leak calibration stand have been networked together with the computer system which maintains records for the entire laboratory. This eliminates any re-keying of data and will significantly reduce data transposition errors.